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(54) Servo circuit for magnetic disk apparatus.

(57) A servo circuit for a magnetic disk apparatus provided with a servo loop which supplies a seek current based on an error signal (DE) between a target speed (El) and real speed (E2) to a voice coil motor (210) and performs speed control on a head carriage (212) toward a target track position, provided in the servo loop with an addition means for adding a predetermined addition value (Ecc) to the error signal (DE) at the stage of acceleration after a start of the speed control or provided, at an amplifier circuit (316) positioned at a latter stage of an amplifier circuit (314) for determining the frequency characteristics of the servo loop, with a gain switching means (318) which switches a preset gain (G1) to a larger gain (G2) between the start of a seek operation and the completion of acceleration.

Fig.10A

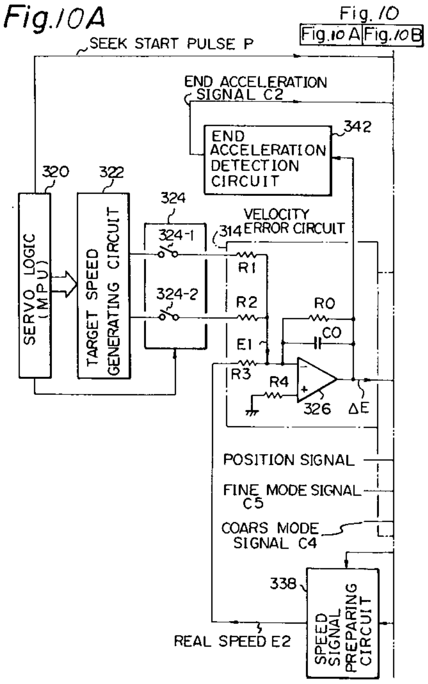

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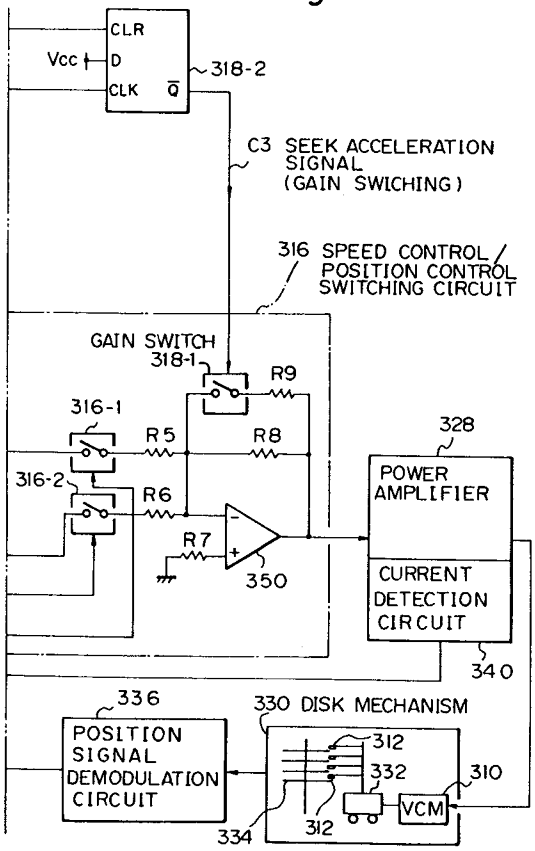
Fig. 10 B


CLR
Vcc
D
CLK
Q̄
318-2
C3 SEEK ACCELERATION SIGNAL (GAIN SWICHING)
316 SPEED CONTROL / POSITION CONTROL SWITCHING CIRCUIT
GAIN SWITCH
318-1
R9
316-1
R5
R8
316-2
R6
R7
350
328
POWER AMPLIFIER
CURRENT DETECTION CIRCUIT
340
336
POSITION SIGNAL DEMODULATION CIRCUIT
330 DISK MECHANISM
312
332
310
VCM
334
312

The present invention relates to a servo circuit for a magnetic disk apparatus which performs speed control over a servo object based on an error between a target speed and a real speed, more particularly relates to ones which perform speed control by passing a seek current corresponding to the error between the target speed and the real speed to a voice coil motor and to one having a speed signal generating circuit for finding the real speed. Circuits of this type are known from our earlier application EP-A-0,272,076.

Servo circuits are used in magnetic disk apparatuses for positioning magnetic heads on specific tracks. In such servo circuits, it is desired to reduce the time required for the speed control and to shorten the access time and to obtain stable positioning even with higher speeds.

In particular, in recent years, higher speeds have been achieved in the seek access operations, which move and stop a head in a disk apparatus at a target track position. Along with the higher speeds of seek access operations, much higher speeds have been sought for so-called "one difference" seek access operations wherein the heads are moved to the adjoining track position. A demand has therefore arisen for a servo circuit with a high response commensurate with the higher speeds of "one difference" seek operations.

Explaining the related art in more detail, in a servo circuit, speed control is used up to near the target position, then position control is switched to so as to control the positioning to the target position. However, the frequency characteristic of the servo object has a resonance point, i.e., a resonance point of the servo arm such as the carriage of the servo object. If the frequency of a speed control signal, explained later, appears in the band which covers this resonance point, mechanical oscillation appears during the seek operation and therefore there is no hope for improvement of the floating stability of the magnetic head and the stability after switching to fine control.

The frequency band of an amplifier of a speed error detection circuit, explained later, is determined by the time constant of a resistor and capacitor of a filter. The cut-off frequency must be made smaller than the resonance point. In recent years, however, higher speed access has become desirable. With a "one difference" seek operation, the acceleration/deceleration current cycle of the speed control signal becomes close to the cut-off frequency. Therefore, the current waveform, in particular, the current waveform during acceleration, becomes corrupted and no further current can be passed. Since it is difficult to raise the resonance point, the problem arises that it is difficult to shorten the time for speed control.

In another related art, provision is made of a servo loop for speed control which generates a target speed in accordance with a difference of a current track position from a target track and supplies to a voice coil motor a seek current corresponding to the difference between the target speed and the real speed. Here, the target speed has the characteristic of maintaining a predetermined maximum speed level when the difference is above a predetermined amount and of falling in proportion to a mean value of the difference, for example, when the difference is under a predetermined amount. The target speed becomes the minimum speed level in the case of a difference of one track.

However, with such a servo circuit, since acceleration is performed by passing a seek current corresponding to the difference between a target speed and real speed, determined by the difference at the start of the seek operation, when the target speed level is extremely small, such as with a "one difference" seek operation, the rise of the acceleration current flowing to the voice coil motor becomes slow.

That is, in a "one difference" seek operation, when the seek current begins to flow at the start of the seek operation and the real speed appears, the target speed level is extremely small, so the difference between the real speed and target speed disappears and the seek current is suppressed. As a result, the seek current at the time of acceleration becomes triangular in form, the rise of the acceleration current deteriorates, and the access time of a "one difference" seek operation becomes longer.

In still another servo circuit, provision is made of an additional speed error preparing circuit. This circuit, however, sometimes suffers from loop resonance, which prevents a normal seek operation. Such loop resonance occurs more easily the larger the seek difference, but if this is prevented by limiting the bands of component circuits so as to try to suppress the oscillation component, the time for the speed control becomes longer and a high speed seek operation, in particular, a high speed seek operation for a small amount of difference such as a difference of one track becomes difficult.

An alternative servo circuit for a magnetic disk apparatus is shown in our co-pending application EP-A-0,378,329 having the same date of filing as the present application. According to this circuit, the cut-off frequency of the speed generating circuit is charged depending on the acceleration and deceleration of the servo object. In a second co-pending application, EP-A-(Attorneys' reference 80/4781/02) also having the same date of filing as the present application, a pre-determined control voltage is added to the acceleration at the start of a seek operation.

According to the present invention, a servo circuit for a magnetic disk apparatus for supplying a seek current based on an error between a target speed and a real speed to a voice coil motor and performing speed control on a servo object toward a target track position, comprises:

a target speed generating means for generating a target speed in accordance with the amount of movement of the servo object;

a speed signal generating means for generating a real speed from a position signal obtained from the servo object;

a speed error preparing means for controlling the speed of the servo object based on the error signal between the target speed and the real speed; and

a gain switching means provided between the speed error preparing means and the voice coil for switching a preset gain to a larger gain between the start of a seek operation and the completion of acceleration.

Examples of the present invention will now be described and contrasted with the prior art with respect to the accompanying drawings, in which:-

Figure 1 and Figs. 2A and 2B are views explaining the prior art;

Fig. 3 is a view explaining problems in the prior art;

Fig. 4 is a view explaining a conventional "one difference" seek operation;

Fig. 5 is a view explaining the constitution of a related servo circuit;

Figs. 6A and 68 are views explaining the operational characteristics of the related servo circuit;

Fig. 7 is a view explaining the constitution of a speed signal generating circuit of the related servo circuit;

Figs. 8A to 8H are views explaining operational waveforms of the speed signal generating circuit of the related servo circuit;

Figs. 9A to 9C are views explaining the present invention;

Fig. 10 is a view of the constitution of an embodiment of the present invention; and

Fig. 11 is an operational timing chart of the present invention.

Before describing the preferred embodiments, a more detailed explanation will be given of the related art for background purposes.

Figure 1 is a view explaining a prior art. In the figure, 11 is a servo object, i.e., a magnetic disk mechanism, which has a voice coil motor 11a, a carriage 11b for carrying a magnetic head 110, and a magnetic disk 11c.

Reference numeral 12 is a position signal demodulation circuit which demodulates a position signal Ps from servo information read from the servo surface of a magnetic disk 11c, 13a is a target speed generating circuit which generates a target speed Vc for positioning to a target position in accordance with an amount of movement from a main processing unit (mentioned later), and 13b is a forward (FWD)/reverse (RVS) switching circuit which switches the target speed of the forward direction or target speed of the reverse direction from the target speed generating circuit 13a in accordance with the forward/reverse switching signal of the main processing unit 18.

Reference numeral 14 is a speed signal preparing circuit which prepares a real speed Vr from a position signal Ps and a current signal ic, mentioned later. Reference numeral 15 is a speed error preparing circuit which generates a speed control current (signal) in accordance with a speed error ΔV between a target speed Vc and a real speed Vr and has an amplifier 150 for generating the speed error ΔV and a filter 151.

Reference numeral 16 is a position error preparing circuit which produces a position error from the position signal Ps and current signal ic and generates a position control signal; and 17a is a coarse/fine switching unit which switches from speed control of the speed error preparing circuit 15 to position control of the position error preparing circuit 16 by a coarse (speed control)/fine (position control) switching signal from the main processing unit.

Reference numeral 17b is a power amplifier which amplifies the output of the switching unit 17a and drives the voice coil motor lla of the magnetic disk mechanism 11; and 17c is a current detection circuit which detects the drive current of the power amplifier 17b and generates a current signal ic.

Reference numeral 18 is a main processing unit which is constituted by a microprocessor, detects the position in accordance with the position signal Ps, outputs a remaining movement to a target speed generating circuit 13a, generates a forward/reverse switching signal in accordance with the forward/reverse direction, and generates a coarse/fine switching signal near the target position.

In this servo circuit, speed control is used up to near the target position, then position control is switched to so as to control the positioning to the target position.

However, the frequency characteristic of the servo object 11 has the resonance point f2 as shown in Fig. 2A.

This resonance point f2 is a torsional resonance point of the servo arm such as the carriage 11b of the servo object 11.

If the frequency of the speed control signal appears in the band which covers this resonance point, mechanical vibration appears during the seek operation (movement) and therefore there is no hope for improvement of the floating stability of the magnetic head 110 and the stability after switching to fine control.

Therefore, the frequency band of the amplifier 150 of the speed error detection circuit 15 is determined by the time constants of the resistor and capacitor of the filter 151, and the cut-off frequency fl of the frequency band shown in Fig. 2B must be made smaller than f2, for example, f2 = 2fl to 1.5 fl.

In recent years, however, higher speed access times have become desirable. With a "one difference" seek operation, as shown in Fig. 3, the acceleration/deceleration current IC cycle of the speed control signal has become close to the cut-off frequency fl. Therefore, as shown by the solid line of Fig. 3, the current waveform of the IC, in particular, the current waveform during acceleration, becomes corrupted and no further current can be passed, as shown by the dotted line. Since it is difficult to raise the resonance point f2 of the mechanical characteristics, the problem arises that it is difficult to shorten the time for speed control.

In another related art, provision is made of a servo loop for speed control which generates a target speed in accordance with a difference of a current track position with a target track and supplies to the voice coil motor a seek current corresponding to the difference between the target speed and the real speed.

Here, the target speed has the characteristic of maintaining the predetermined maximum speed level when the difference is above a predetermined value and of falling in proportion to a mean value of the difference, for example, when the difference is below a predetermined value. The target speed becomes the minimum speed level when there is a difference of one track.

However, with such a servo circuit, since acceleration is performed by passing a seek current corresponding to a difference between the target speed and real speed determined by the difference at the start of the seek operation, when the target speed level is extremely small, such as with a "one difference" seek operation, the rise of the acceleration current flowing to the voice coil motor becomes slow.

That is, as shown in Fig. 4, in a "one difference" seek operation, when the seek current begins to flow at the start of the seek operation at the time tl and the real speed appears, the target speed level is extremely small, so the difference between the real speed and target speed disappears and the seek current is suppressed. As a result, the seek current at the time of acceleration becomes triangular in form, the rise of the acceleration current OA deteriorates, and the access time of a "one difference" seek operation becomes longer.

Figure 5 is a block diagram showing the basic constitution of another servo circuit previously proposed by the applicant to meet this demand ("related" servo circuit). In Fig. 5, reference numeral 411 is a magnetic disk mechanism used as the servo object. This is provided with a voice coil motor VCM 4111, a carriage 4113 mounting a magnetic head 4112, and a magnetic disk 4114.

Reference numeral 412 is a position signal demodulation circuit which demodulates a position signal Ps showing the position of movement from servo information read by the servo head 4112 from the servo surface of the magnetic disk 4114.

Reference numeral 413 is a target speed generating circuit which generates a target speed Vc for positioning the magnetic head 4112 of the servo object 411 at a target position in accordance with an amount of movement commanded by a main processing unit.

Reference numeral 414 is a speed signal generating circuit which prepares a real speed Vr of the magnetic head 4112 in the servo object 411 from the position signal Ps and the current signal ic. The current signal ic is a compensating signal which is added for the smooth production of the real speed Vr.

Reference numeral 415 is a speed error preparing circuit which is provided internally with a filter 4150 and generates a speed error signal ΔV for controlling the servo object 411 based on a speed error between the target speed Vc and the real speed Vr.

Reference numeral 416 is a position error preparing circuit which produces a position error of the servo object 411 with respect to a target position from the position signal Ps and the current signal ic and generates the position control signal ΔP.

Reference numeral 417 is a servo object drive circuit which performs processing for switching from speed control by the speed error preparing circuit 415 to the position control of the position error preparing circuit 416 by a coarse (speed control)/fine (position control) switching signal from the main processing unit, amplifies the power of the error signal ΔV or ΔP, performs processing for outputting the voice coil motor current Ic for driving the voice coil motor 4111 of the servo object 411, detects the voice coil motor current Ic, and performs processing for generating the current signal ic.

Reference numeral 418 is a main processing unit which is constituted by a microprocessor, detects the position of the magnetic head 4112 based on the position signal Ps, outputs the remaining amount of movement, i.e., the remaining difference, to the target speed generating circuit 413, and generates a coarse/fine switching signal near the target speed.

Reference numeral 419 is an acceleration detecting circuit, which detects the speed error signal ΔV generated by the speed error preparing circuit 415 and generates an acceleration-in-progress signal SKA which changes the band of the speed error preparing circuit 415 in accordance with the amount of seek difference during acceleration and deceleration.

The servo circuit constructed as above performs speed control up to near the target position and then switches to position control and performs control for positioning to the target position. This control operation is basically the same as the servo control operations of conventional servo circuits, so the remaining explanation will primarily concentrate on the operation of the speed error preparing circuit 415 referring to Figs. 6A and 6B.

When the speed control starts due to a command from the main processing unit 418, the target speed generating circuit 413 generates a target speed Vc during acceleration control from the amount of movement, that is, amount of difference, commanded by the main processing unit 418.

Further, the speed signal generating circuit 414 receives the position signal Ps from the position signal demodulation circuit 412 and the current signal ic from the servo object drive circuit 417 and prepares a real speed Vr of the servo object 411 (magnetic head).

The speed error preparing circuit 415 generates a speed error signal ΔV corresponding to the speed error between the target speed Vc generated by the target speed generating circuit 413 and the real speed Vr generated by the speed signal generating circuit 414.

On the other hand, the acceleration detecting circuit 419 detects from the speed error signal ΔV generated by the speed error preparing circuit 415 that the speed error preparing circuit 415 is in the middle of acceleration control and thereupon adds the acceleration-in-progress signal SKA to the speed error preparing circuit 415.

When the filter 4150 of the speed error preparing circuit 415 receives the acceleration-in-progress signal SKA from the acceleration detecting circuit 419, the cut-off frequency f10 becomes infinitely large or higher than even the resonance point f2 of the servo object 411. Due to this, the cut-off frequency f10 of the speed error preparing circuit 415 during acceleration control becomes infinitely large or higher than even the resonance point f2 of the servo object 411 as shown in Fig. 6A. The finitely large cut-off frequency f10 in this case is set to a high frequency in a range where no oscillation will occur in the acceleration current.

The servo object drive circuit 417 amplifies the power of the speed error signal ΔV received from the speed error preparing circuit and outputs the voice coil motor current Ic for driving by acceleration the voice coil motor 4111 of the servo object 411 and also generates a current signal ic, i.e., the detected current of the voice coil motor current Ic.

By this, the curve of the voice coil motor current Ic corresponding to the speed error signal ΔV generated by the speed error preparing circuit 415 during acceleration control becomes a very clean, sharply inclined one, as shown by Fig. 6B, so it is possible to end the acceleration control in a short time.

When the acceleration control is ended, the main processing unit 418 switches to deceleration control.

When deceleration control is switched to upon the command of the main processing unit 418, the target speed generating circuit 413 generates a target speed Vc for deceleration control. The speed error preparing circuit 415 generates a speed error signal ΔV (negative) corresponding to the speed error between a target speed Vc generated by the target speed generating circuit 413 and the real speed Vr generated by the speed signal generating circuit 414.

On the other hand, the acceleration detecting circuit 419 stops the generation of the acceleration-in-progress signal SKA upon completion of the acceleration control of the speed error preparing circuit 415.

When the speed error preparing circuit 415 enters deceleration control, the filter 4150 of the speed error preparing circuit 415 lowers the cut-off frequency to a frequency below the resonance point f2 of the servo object 411. At this time, the larger the difference, the lower the cut-off frequency is made. By this, the cut-off frequency of the speed error preparing circuit 415 during deceleration control is reduced to f11, fl2, ... fln the larger the amount of difference, as shown in Fig. 6A.

The servo object drive circuit 417 amplifies the power of the speed error signal ΔV received from the speed error preparing circuit 415 and outputs a voice coil motor current Ic corresponding to the seek current for controlling under deceleration the voice coil motor 4111 and also generates a current signal ic, i.e., the detected current of the voice coil motor current Ic.

By this, the curve of the deceleration current, i.e., the voice coil motor current Ic corresponding to the speed error signal ΔV generated by the speed error preparing circuit 415 during deceleration control, becomes as shown in Fig. 6B. That is, there is less corruption of the deceleration curve the smaller the amount of difference, and the deceleration control time, that is, the speed control time, falls such as tn, ... t2, tl.

In the above way, the cut-off frequency of the speed error preparing circuit is made to change between the times of acceleration control and deceleration control and also the cut-off frequency during deceleration control is made to change in accordance with the amount of difference, so during acceleration control, the corruption of the acceleration current supplied to the servo object can be reduced and the degree of the corruption of the deceleration current during deceleration control can be reduced the less the amount of difference, so even when the amount of difference is small, it is possible to stably shorten the speed control time. By this, it is possible to perform speed control stably and at a high speed even with an extremely small difference such as a difference of one track and thus stable, high speed seek operations become possible.

Next, an explanation will be made of the constitution and operation of the speed signal generating circuit 414 referring to Fig. 7 and Figs. 8A to 8H. In Fig. 7, reference numeral 4141 is a differential circuit which differentiates the position signal Ps and generates a differential speed Vps. Reference numeral 4143 is an amplifier which amplifies the current signal ic up to a predetermined level.

Reference numeral 4144 is an offset adjusting circuit which generates an offset compensating signal for adjusting the offset of the real speed Vr generated from the speed signal generating circuit 414.

Reference numerals 4145a to 4145c are variable resistors, the variable resistor 4145a being used to adjust the output gain of the amplifier 4143a, the variable resistor 4145b being used to adjust the output gain of the differential circuit 4141, and the variable resistor 4145c being used to adjust the output gain of the offset adjusting circuit 4144.

Reference numeral 4142 is a real speed generating circuit, which amplifies and integrates the added signal of the level adjusted differential signal Vps, current speed ic, and the offset signal and prepares the real speed Vr.

In this construction, the position signal Ps shown in Fig. 8A is applied to the differential circuit 4141 from the position signal demodulation circuit 412. The position signal Ps has a waveform which crosses zero each time the magnetic head passes through the track. The differential circuit 4141 differentiates the position signal Ps and generates a differential speed Vps shown in Fig. 8B. This differential speed Vps becomes zero at each of the largest points of the position signal Ps and peaks at the each point where it crosses zero. The envelope connecting the peaks gives the real speed Vr of the servo object 411 (magnetic head).

If just the differential signal Vps generated from the differential circuit 4141 is given to the real speed generating circuit 4142, differentiation is performed and the envelope of the differential speed Vps is obtained. In this case, at places where the peak interval of the differential speed Vps is small, that is, at places of fast speed of the Vr, a good envelope characteristic is obtained, but at places with large peak intervals, that is, places of slow speed (starting and ending times of seek operations), good envelope characteristics cannot be obtained. To correct the deviations in the envelope characteristics, the current signal ic may be added.

The current signal ic shown in Fig. 8C from the servo object drive circuit 417 is amplified by the amplifier 4143 and added to the differential speed Vps. The current signal ic resembles the voice coil motor current Ic supplied to the servo object, so can effectively correct the deviations in the envelope mentioned earlier.

The real speed generating circuit 4142 integrates and amplifies the added signal of the differential speed Vps, the current signal ic, and the offset correction signal and generates a real speed Vr having a smooth characteristic shown in Fig. 8D. Note that since an accurate real speed Vr is produced, the output gains of the current signal ic, the differential speed Vps, and the offset correction signal are initialized by the variable resistors 4145a to 4145c.

The speed signal generating circuit 414 in the related servo circuit has a fixed frequency band irregardless of the seek difference. The band of the speed signal generating circuit 414 is defined by the band of the real speed generating circuit 4142, that is, the time constants of the integration resistor 4142b and capacitor 4142c.

Therefore, when oscillation is generated during seek acceleration control due to the mechanical resonance of the servo object 411, as shown in Fig. 8E, the position signal Ps takes on a waveform with the oscillation superposed. When the amount of movement of the servo object 411 (magnetic head), that is, the amount of seek difference, is large, the acceleration time and the acceleration voice coil motor current Ic become large, so oscillation readily occurs.

When oscillation is generated in the position signal Ps in this way, oscillation is also caused in the differential speed Vps as shown in Fig. 8F, and oscillation is caused in the real speed Vr generated by the real speed generating circuit 4142 (Fig. 8G).

Since this oscillating real speed Vr is received and oscillation occurs in the speed error signal ΔV generated by the speed error preparing circuit 415, oscillation also occurs in the voice coil motor current Ic generated by the servo object drive circuit 417 (Fig. 8H).

As a result, the amplitude of the servo object 411 is amplified, loop resonance occurs, and a normal seek operation is no longer possible. Such loop resonance occurs more easily the larger the seek difference, but if this is prevented by limiting the bands of one or both of the speed signal generating circuit 414 and the speed error preparing circuit 415 so as to try to suppress the oscillation component, the time for the speed control becomes longer and a high speed seek operation, in particular, a high speed seek operation with a small amount of difference such as a difference of one track, becomes difficult. This is a problem of not only the related servo circuit, but conventional servo circuits as well.

According to the present invention, there is provided a servo circuit for a magnetic disk apparatus provided with a servo loop which supplies a seek current based on an error signal ΔE between a target speed E1 (Vc) and real speed E2 (Vr) to a voice coil motor 310 and performs speed control on a carriage carried head 312 toward a target track position, the servo circuit provided, at an amplifier circuit 316 positioned at a latter stage of an amplifier circuit 314 for determining the frequency characteristics of the servo loop, with a gain switching means 318 which switches a preset gain Gl to a larger gain G2 between the start of a seek operation and the completion of acceleration as shown in Fig. 9B.

Preferably, the gain switching means 318 is provided in a speed control/speed control switching circuit 316 provided at a latter stage of a velocity error circuit 314 which determines the frequency characteristic of the servo loop.

In the servo circuit of a magnetic disk apparatus according to the present invention, even when the acceleration/deceleration current cycle during a "one difference" seek operation becomes a value close to the cut-off frequency of the amplifier, during the acceleration period, the gain of the servo loop is amplified to a high gain compulsorily after the circuit portions which determine the frequency characteristic of the servo loop, so it is possible to quickly raise the acceleration current and achieve sufficient acceleration without the limitations of the cut-off frequency of the servo loop and it is possible to achieve faster access in a "one difference" seek operation.

Figure 10 is a view of the constitution of an example of the present invention. The servo loop of the present invention is constituted by a servo logic 320, a target speed generating circuit 322, a forward/reverse switching circuit 324, a velocity error circuit 314, a speed control/position control switching circuit 316, a power amplifier 328 provided with a current detection circuit 340, a voice coil motor 310, a head carriage 332, and disk mechanism 330 provided with a head 312 and a disk medium 334, a position signal demodulation circuit 336, a speed signal preparing circuit 338, and an end acceleration detection circuit 342.

The velocity error circuit 314 obtains the error between the reverse or forward target speed voltage E1 from the target speed generating circuit 322 input through the forward/reverse switching circuit 324 and the real speed voltage E2 given from the speed signal preparing circuit 338 and generates an error signal GE. The velocity error circuit 314 is provided with an amplifier 326. The feedback circuit of the amplifier 326 has connected in parallel a resistor R0 and a capacitor C0, the time constants of R0 and C0 determining the frequency characteristic of the velocity error circuit 314, i.e., the frequency characteristic of the servo loop. The cut-off frequency fl is set to a frequency lower than the mechanical cut-off frequency f2 in the disk mechanism 330, that is, the mechanical cut-off frequency f2 determined by the torsional resonance point of the servo arm.

The speed control/position control switching circuit 316 provided in the velocity error circuit 314 is provided with a switch 316-1 which is turned on by a coarse mode signal (speed control mode signal) C4 and a switch 316-2 which is turned on by the fine mode signal (position control mode signal) C5. It receives as input the error signal ΔE output from the velocity error circuit 314 through the switch 316-1 and receives as input the position signal from a not shown position signal generating circuit through the switch 316-2. The output of the switch 316-1 is input to the amplifier 350 through the resistor R5 and the output of the switch 316-2 is input through the resistor R6. The amplifier 350 has a resistor R8 and resistor R9 connected in parallel in the feedback circuit. One of the resistors, R9, is connected in series to the gain switch 318-1. The gain switch 318-1 is usually on. Therefore, the gain G1 of the amplifier 350 in the steady state is determined by the value of the parallel resistors R8 and R9. On the other hand, when the gain switch 318-1 is turned off and the resistor R9 is cut off from the feedback circuit, the gain of the amplifier 350 becomes a high gain G2 determined by the resistor R8.

The gain switch 318-1 is controlled to turn on and off by the D-flip-flip 318-2 provided as the gain switching control means. The clock terminal CLK of the D-flip-flop 318-2 has applied to it the end acceleration signal C2 from the end acceleration detection circuit 342. The D terminal has input to it an end acceleration signal C2 through a capacitor. Further, the clear terminal CLR receives as input the seek start pulse P2 from the servo logic 320.

Therefore, in the steady state, the D-flip-flop 318-2 is placed in a reset state, the seek acceleration signal C3, which becomes the $\overline{Q}$ output, is at a low level, and therefore the gain switch 318-l turns on and the steady state gain G1 is set in the amplifier 350 by the value of the parallel resistors R8 and R9. When an access is received from the host computer and the servo logic 320 generates a seek start pulse P, the D-flip-flop 318-2 is cleared, the seek acceleration signal C3 serving as the $\overline{Q}$ output becomes the high level, and the gain switch 318-1 turns off, whereby the resistor R9 is cut off from the feedback circuit and the amplifier 350 is switched to the higher gain G2. The D-flip-flop 318-2 reset by the seek start pulse P is again set by the end acceleration signal C2 from the end acceleration detection circuit 342 obtained next, and the acceleration signal C3 returns to the low level, whereby the gain switch 318 turns on and the original gain Gl is returned to.

Next, an explanation will be made of the operation of the example of Fig. 10 referring to the operational timing chart of Fig. 11.

In Fig. 11, first, assume that at the time tl, the servo logic 320 receiving the access from the host computer starts the forward control. That is, the servo logic 320 supplies the target speed generating circuit 322 with the target speed data corresponding to the amount of difference from the target track at that time, the target speed generating circuit 322 generates a target speed voltage by analog to digital conversion, and the forward switch 324-1 of the forward/reverse switching circuit turns on by the forward control command from the servo logic 320, so the target speed voltage E1 for the forward control is supplied to the velocity error circuit 314 through the switch 324-1.

In the initial state, the real speed voltage E2 from the speed signal preparing circuit 338 is zero, so the error signal DE output from the amplifier 326 provided in the velocity error circuit 314 is maximum. The maximum level error signal ΔE is input to the amplifier 350 of the speed control/position control switching circuit 316 through the switch 316-1 turned on by the coarse mode signal C4. At that time, since the D-flip-flop 318-2 receives the seek start pulse P from the servo logic 320 at the time tl and is in the reset state, the gain switch 318-1 provided in the feedback circuit of the amplifier 350 receives the seek acceleration signal C3, where $\overline{Q}$ is the high level, and is switched off. The resistor R9 is cut off from the feedback circuit, so the switch is set to the higher gain G2 determined by the resistor R8.

Therefore, the error signal ΔE from the velocity error circuit 314 is amplified by the amplifier 350 by the higher gain G determined by the resistance R8, a seek current corresponding to the error signal ΔE is created by the power amplifier 328, and an acceleration current is passed to the voice coil motor 310 of the disk mechanism 330.

The voice coil motor 310, which receives the acceleration seek current from the power amplifier 328, starts the speed control for moving the head 312 by the carriage 332 to the target track position of the disk medium 334. Along with the speed control, the speed signal preparing circuit 338 prepares the real speed voltage E2 based on the position signal from the position signal demodulation circuit 336 and the current detection signal from the current detection circuit 340 provided in the power amplifier 328, and servo control is performed for feedback to the velocity error circuit 314.

When the real speed voltage E2 increases under this servo control and the target speed voltage E1 is reached, the error signal DE from the amplifier 326 becomes zero voltage, so the fact that the zero voltage has been reached is detected by the end acceleration detection circuit 342, the end acceleration signal C2 rises to a high level with respect to the D-flip-flop 318-2 as shown at the time t2 in Fig. 11, and the D-flip-flop 318-2, which had been in the reset state up until then, is returned once again to the set state at the time of detection of the end of the acceleration. Therefore, the seek acceleration signal C3, which serves as the $\overline{Q}$ output, returns to the low level from the high level, and the gain switch 318-1 turns on, whereby the resistor R9 is connected to the feedback circuit and the original gain G1 is returned to.

That is, the amplifier 350 switches the normal gain Gl to the higher gain G2 in the period from the start of the seek operation to the end of the acceleration.

At the time t2, after the end of the acceleration, deceleration control is performed based on the error signal ΔE between the target speed voltage E1 and the real speed voltage E2. At the time t3, the difference from the target track becomes zero, the switch 316-2 turns on due to the fine mode signal C5 from the servo logic 320, and position control (fine control) is switched to for control so that the head traces the target track.

Compared with this "one difference" seek operation of the present invention, the one difference seek operation of the related art suffered from the effects of the cut-off frequency fl in the frequency characteristic determined by the time constants of the resistor R0 and the capacitor C0 provided in the velocity error circuit 314. As shown in Fig. 11, the constant gain seek current of the servo loop of the related art rose slowly during acceleration. If the seek operation is considered to begin at the time tl, a long seek time T2 extending until the time t4 is required compared with the seek time T1 of the third aspect of the present invention.

As opposed to this, in the present invention, even if the cycle of the acceleration/ deceleration period of the seek current in a "one difference" seek operation approaches the cut-off frequency fl of the servo loop, the gain of the amplifier 320 provided in the speed control/position control switching circuit 316 at the latter stage of the velocity error circuit 314 determining the frequency characteristic of the servo loop is switched to a higher gain during the acceleration, so the seek current during the acceleration period can be raised well without being limited by the frequency characteristic of the servo loop and sufficient acceleration is made possible, whereby it is possible to greatly reduce the access time in a "one difference" seek operation and realize high speed access.

Further, in the above embodiment, provision was made in the velocity error circuit 314 of circuit elements for determining the frequency characteristic of the servo loop, so a gain switching means was provided in the speed control/position control switching circuit 316 serving as the latter stage of the velocity error circuit 314, but the third aspect of the present invention is not limited to this and it is of course possible to provide, in a suitable portion of the amplifier circuit positioned at the latter stage of the amplifier circuit determining the frequency characteristic in the loop of the servo circuit, a gain switching means for switching to a gain higher than the usual gain in the period from the start of the seek operation to the end of the acceleration.

As explained above, even in a "one difference" seek operation where the acceleration/deceleration period of the seek current is a value close to the cut-off frequency of the servo loop, it is possible to quickly raise the acceleration current and sufficiently accelerate without being limited by the cut-off frequency of the servo loop and it is possible to achieve a much faster access in a "one difference" seek operation.

Claims

1. A servo circuit for a magnetic disk apparatus for supplying a seek current based on an error between a target speed and a real speed to a voice coil motor (310) and performing speed control on a servo object (332) toward a target track position, comprising:

a target speed generating means (322) for generating a target speed in accordance with the amount of movement of the servo object (332);

a speed signal generating means (338) for generating a real speed from a position signal obtained from the servo object (332);

a speed error preparing means (314) for controlling the speed of the servo object (332) based on the error signal between the target speed and the real speed; and

a gain switching means (316) provided between the speed error preparing means (314) and the voice coil (310) for switching a preset gain to a larger gain between the start of a seek operation and the completion of acceleration.

2. A servo circuit as claimed in claim 1, wherein the switching of the gain switching means is performed by a seek acceleration signal obtained from a seek start pulse and an end acceleration signal.

Fig. 1

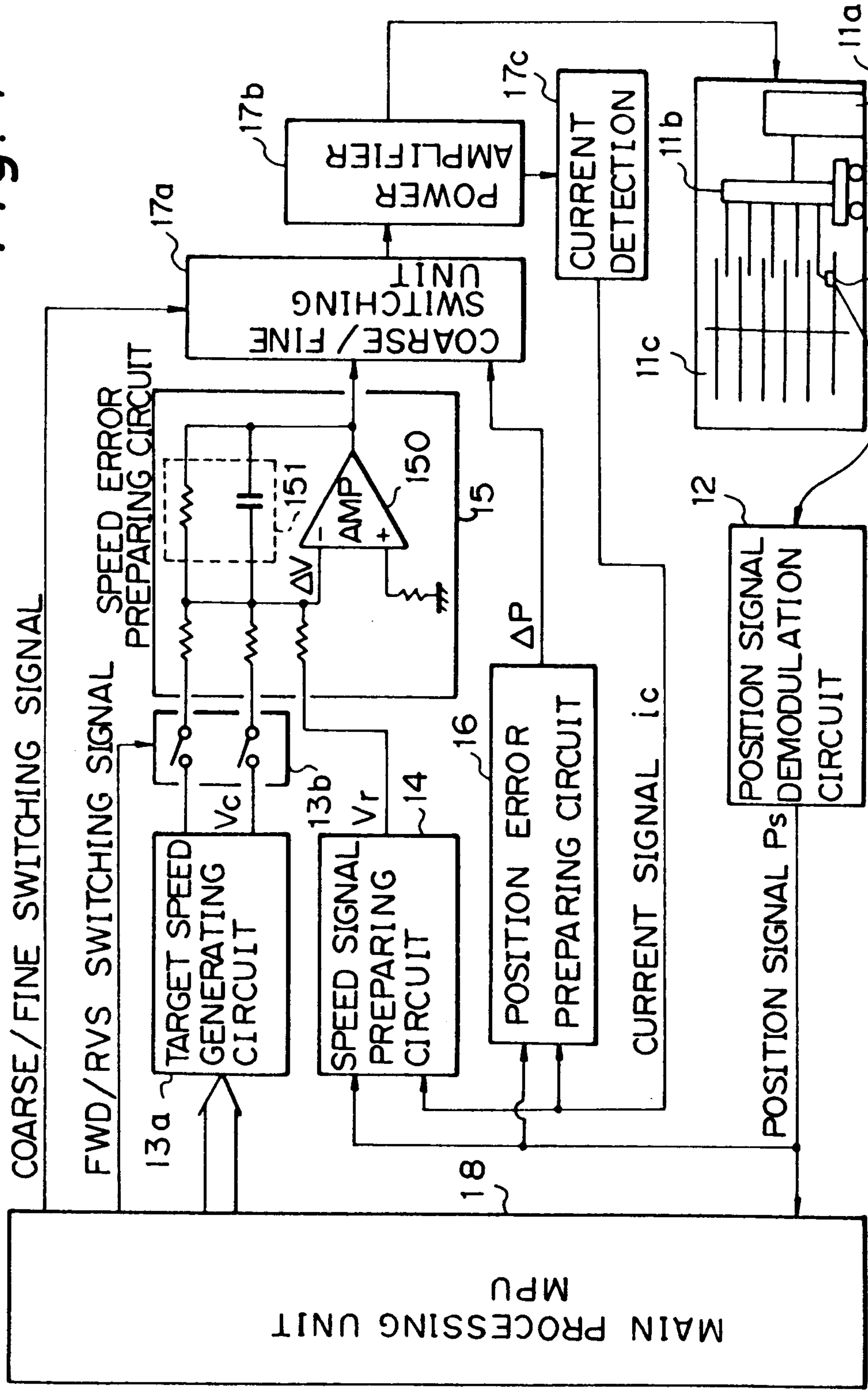

COARSE/FINE SWITCHING SIGNAL
FWD/RVS SWITCHING SIGNAL
13a
TARGET SPEED GENERATING CIRCUIT
Vc
13b
Vr
14
SPEED SIGNAL PREPARING CIRCUIT
SPEED ERROR PREPARING CIRCUIT
151
AMP
150
ΔV
15
16
POSITION ERROR PREPARING CIRCUIT
ΔP
CURRENT SIGNAL ic
POSITION SIGNAL Ps
17a
COARSE/FINE SWITCHING UNIT
17b
POWER AMPLIFIER
17c
CURRENT DETECTION
12
POSITION SIGNAL DEMODULATION CIRCUIT
11a
11b
11
110
11c
18
MAIN PROCESSING UNIT
MPU

Fig. 2A

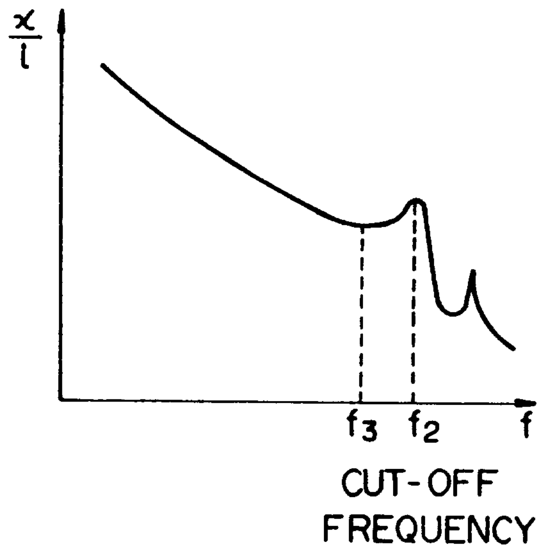


Fig. 2B

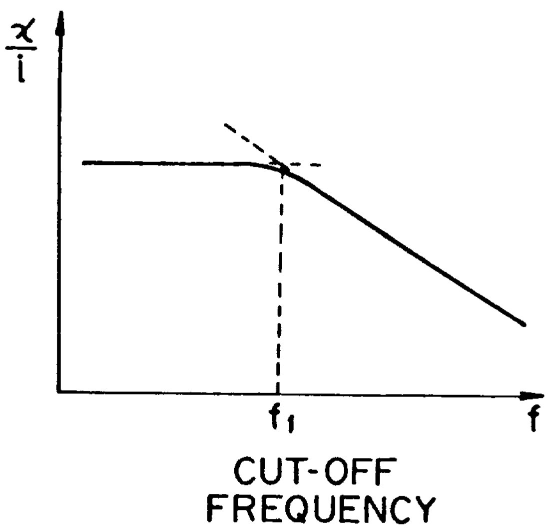


Fig. 3

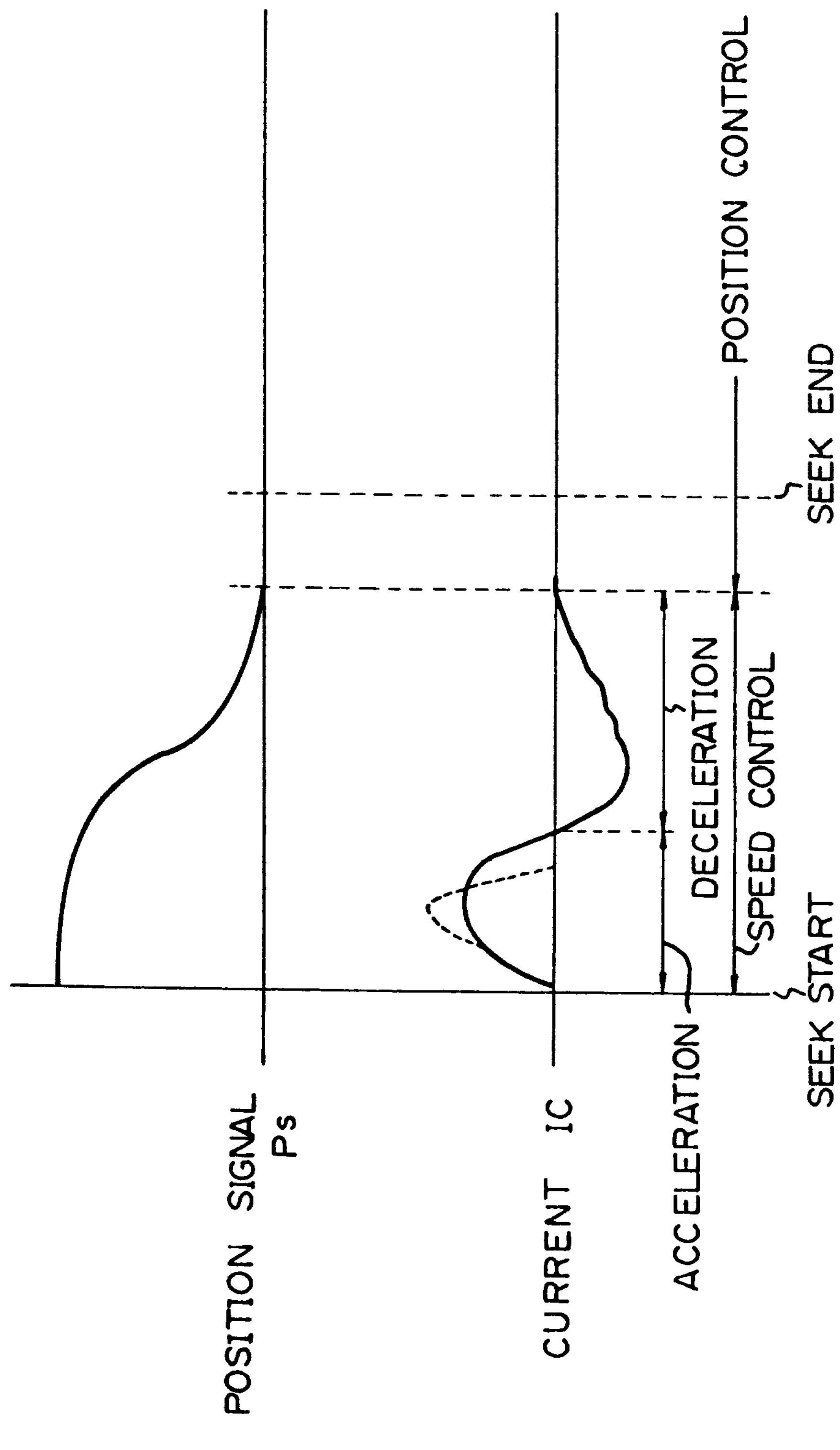

POSITION SIGNAL Ps
CURRENT IC
ACCELERATION
DECELERATION
SPEED CONTROL
POSITION CONTROL
SEEK START
SEEK END

Fig. 4

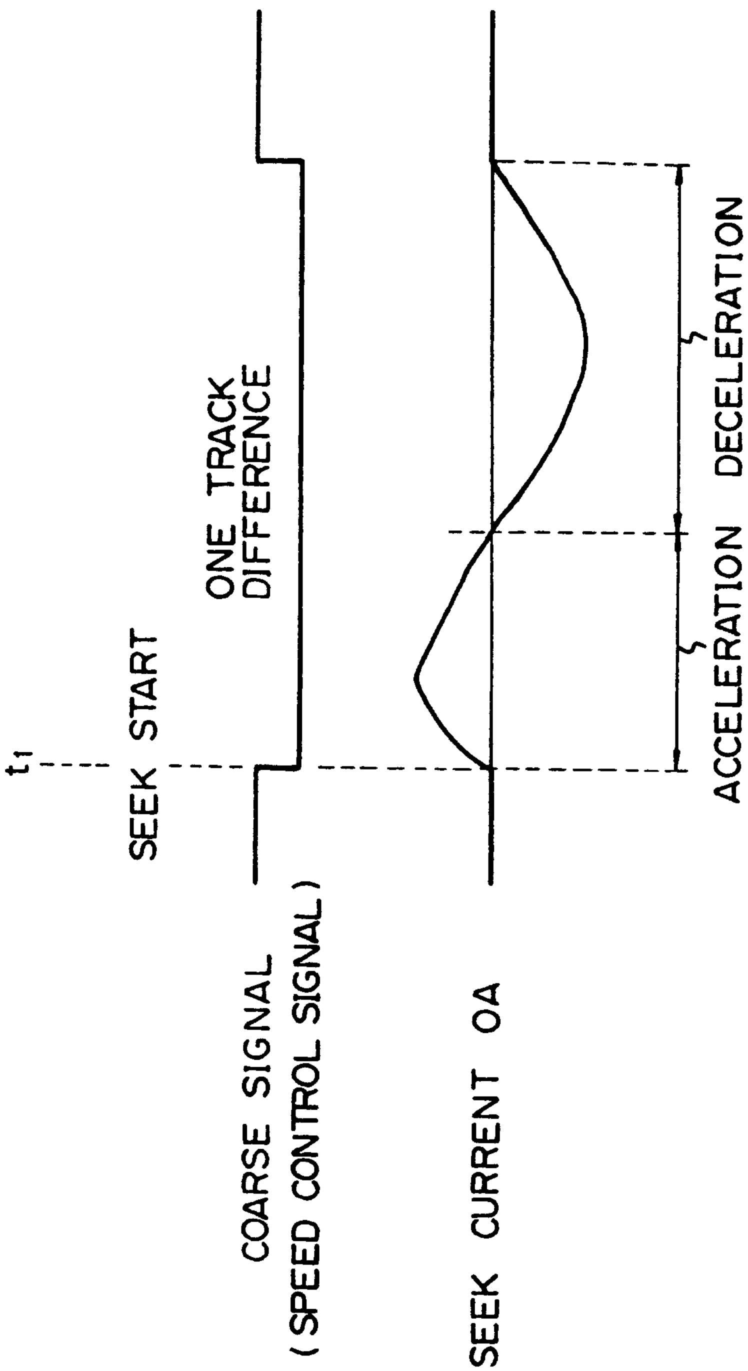

t1
SEEK START
ONE TRACK
DIFFERENCE
COARSE SIGNAL
(SPEED CONTROL SIGNAL)
SEEK CURRENT OA
ACCELERATION
DECELERATION

Fig. 5

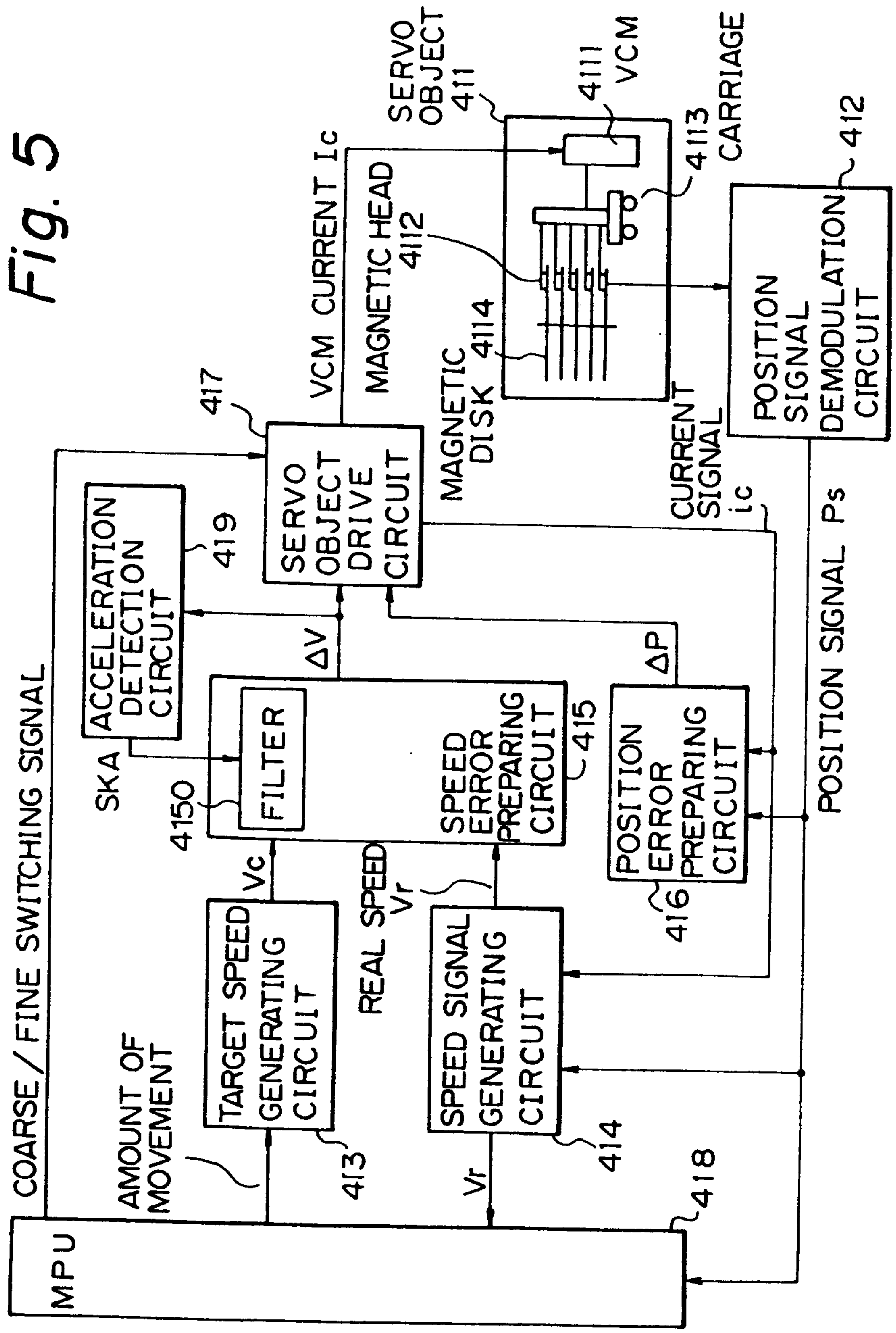

SERVO OBJECT 411
4111 VCM
4113 CARRIAGE
412
VCM CURRENT Ic
MAGNETIC HEAD 4112
MAGNETIC DISK 4114
417
SERVO OBJECT DRIVE CIRCUIT
POSITION SIGNAL DEMODULATION CIRCUIT
CURRENT SIGNAL ic
POSITION SIGNAL Ps
ACCELERATION DETECTION CIRCUIT
419
ΔV
ΔP
SKA
4150
FILTER
SPEED ERROR PREPARING CIRCUIT
415
POSITION ERROR PREPARING CIRCUIT
416
COARSE / FINE SWITCHING SIGNAL
AMOUNT OF MOVEMENT
TARGET SPEED GENERATING CIRCUIT
413
Vc
REAL SPEED Vr
SPEED SIGNAL GENERATING CIRCUIT
414
Vr
MPU
418

Fig. 6A

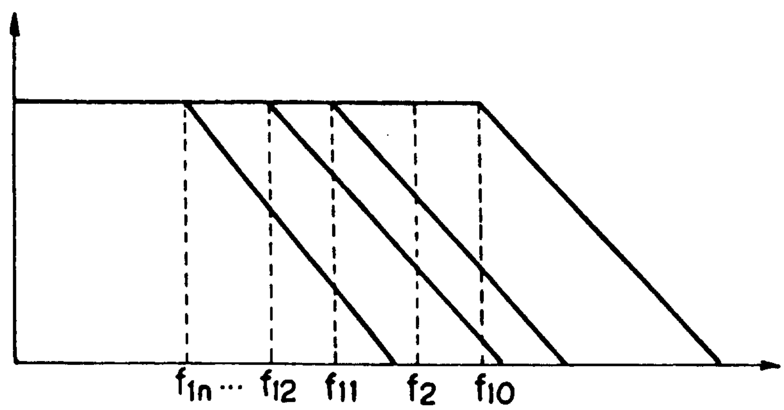

f1n ··· f12 f11 f2 f10

Fig. 6B

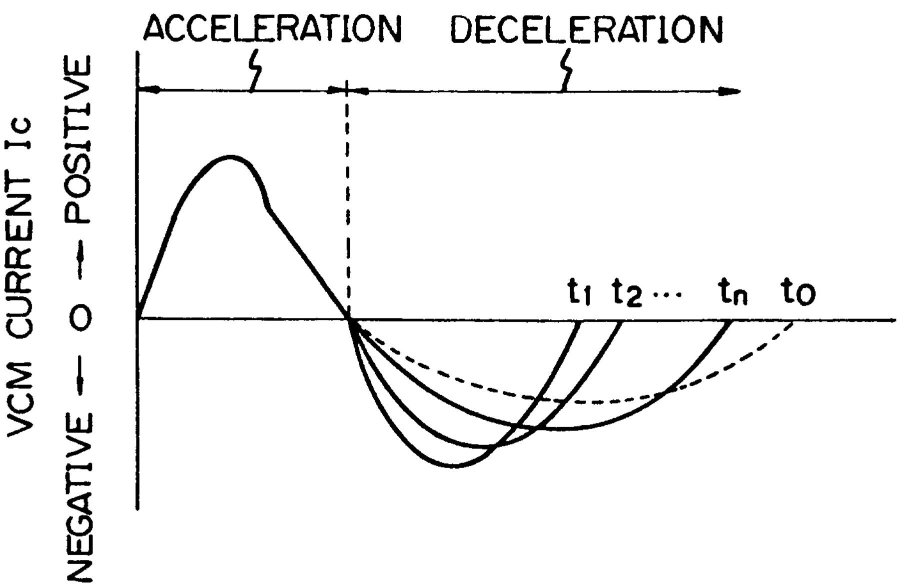

ACCELERATION
DECELERATION
VCM CURRENT Ic
NEGATIVE ← O → POSITIVE
t1 t2 ··· tn to

Fig. 7

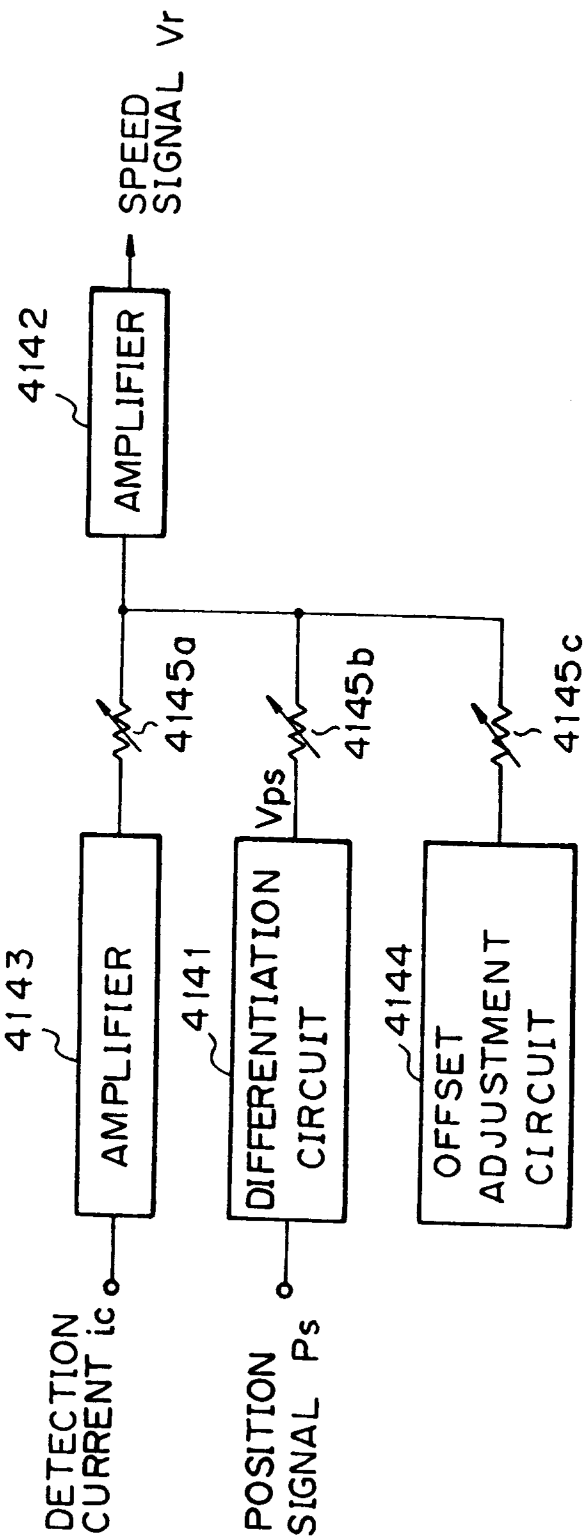

SPEED SIGNAL Vr
4142
AMPLIFIER
4145a
4145b
4145c
Vps
4143
AMPLIFIER
4141
DIFFERENTIATION CIRCUIT
4144
OFFSET ADJUSTMENT CIRCUIT
DETECTION CURRENT ic
POSITION SIGNAL Ps

Fig. 8A

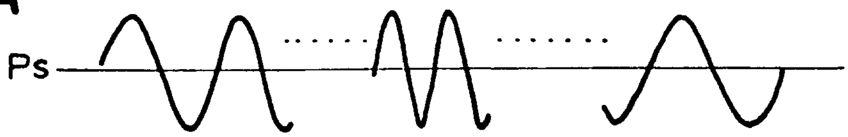


Fig. 8B

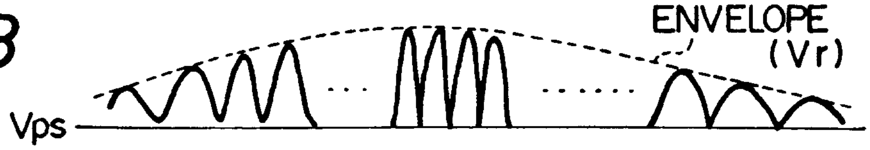


Fig. 8C

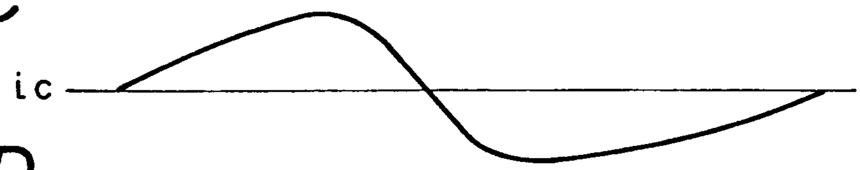


Fig. 8D

Fig. 8E

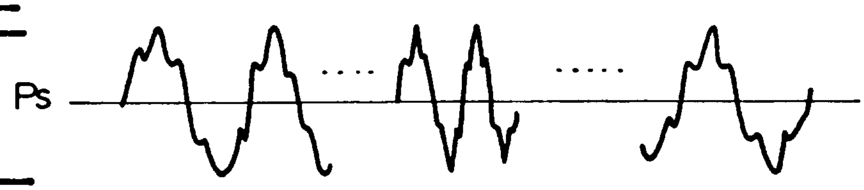


Fig. 8F

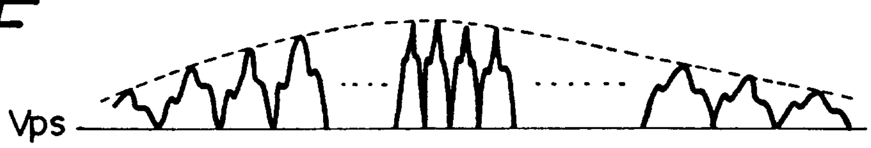


Fig. 8G

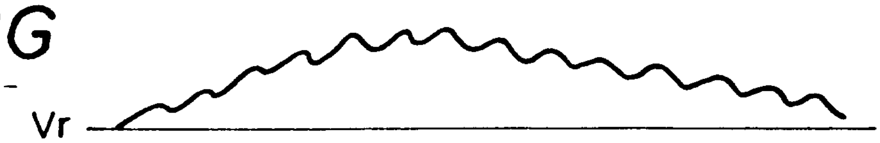


Fig. 8H

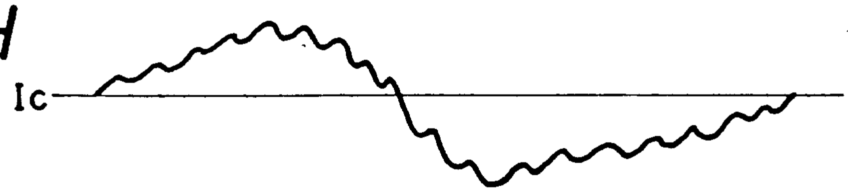
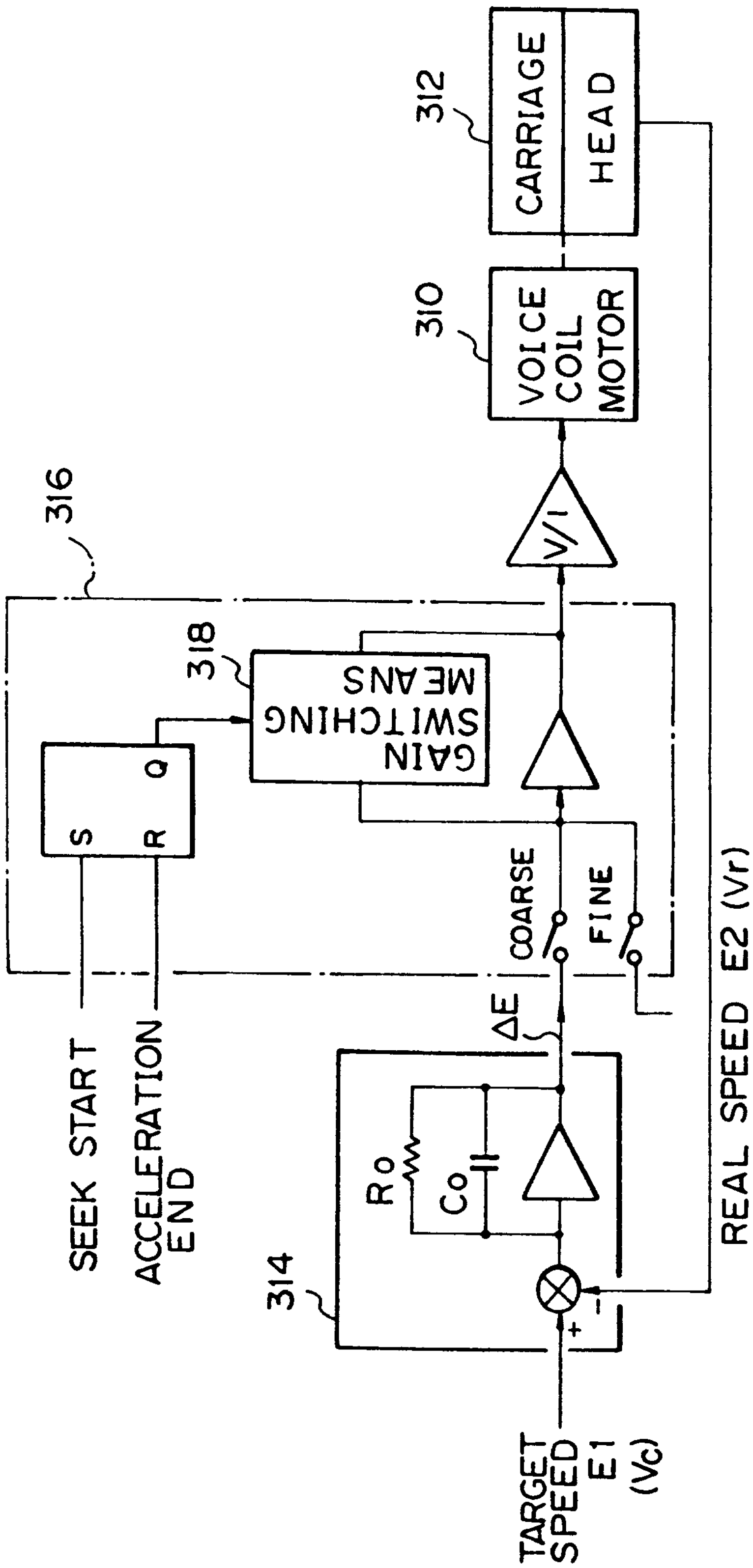


Fig. 9 A



312
CARRIAGE
HEAD
310
VOICE COIL MOTOR
316
V/I
318
GAIN SWITCHING MEANS
S
R
Q
COARSE
FINE
SEEK START
ACCELERATION END
ΔE
Ro
Co
314
TARGET SPEED E1 (Vc)
REAL SPEED E2 (Vr)

Fig. 9 B

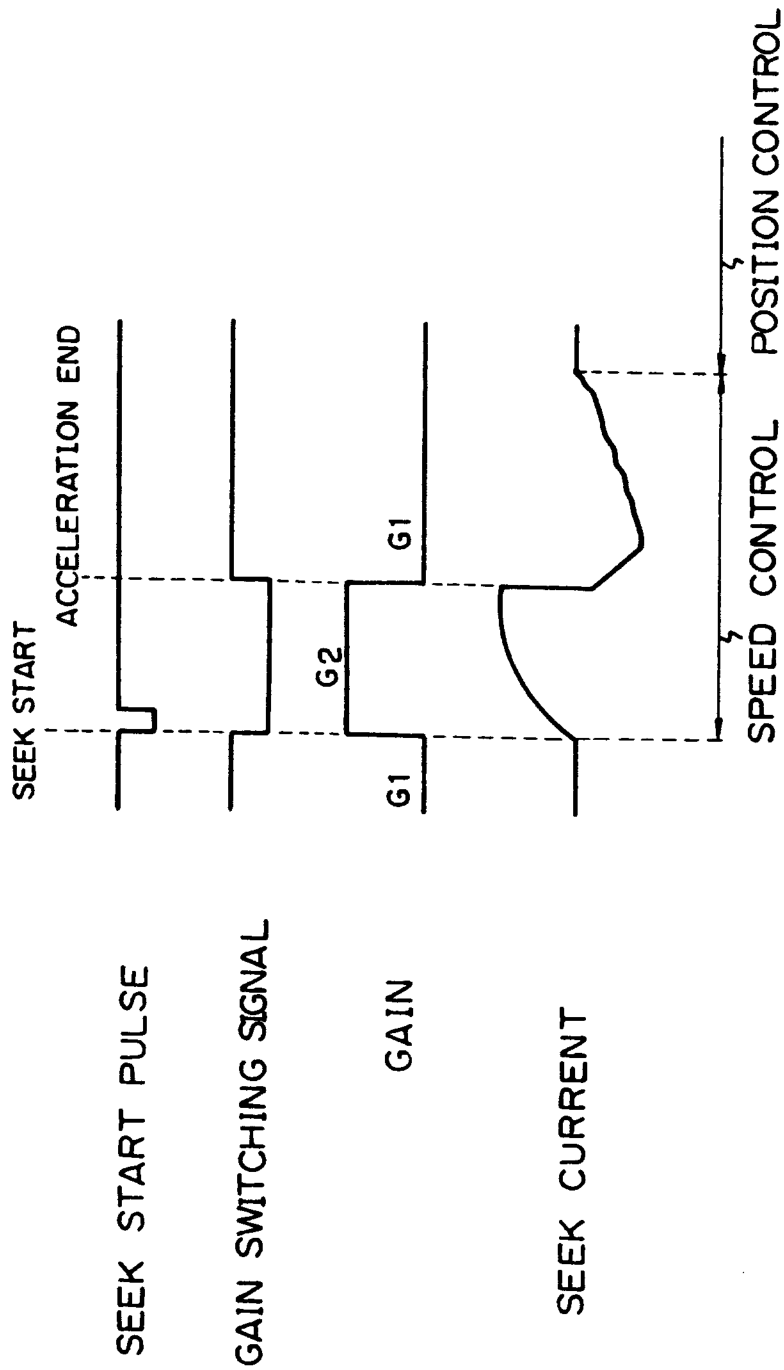

SEEK START
ACCELERATION END
SEEK START PULSE
GAIN SWITCHING SIGNAL
GAIN
G1
G2
G1
SEEK CURRENT
SPEED CONTROL
POSITION CONTROL

Fig.10A

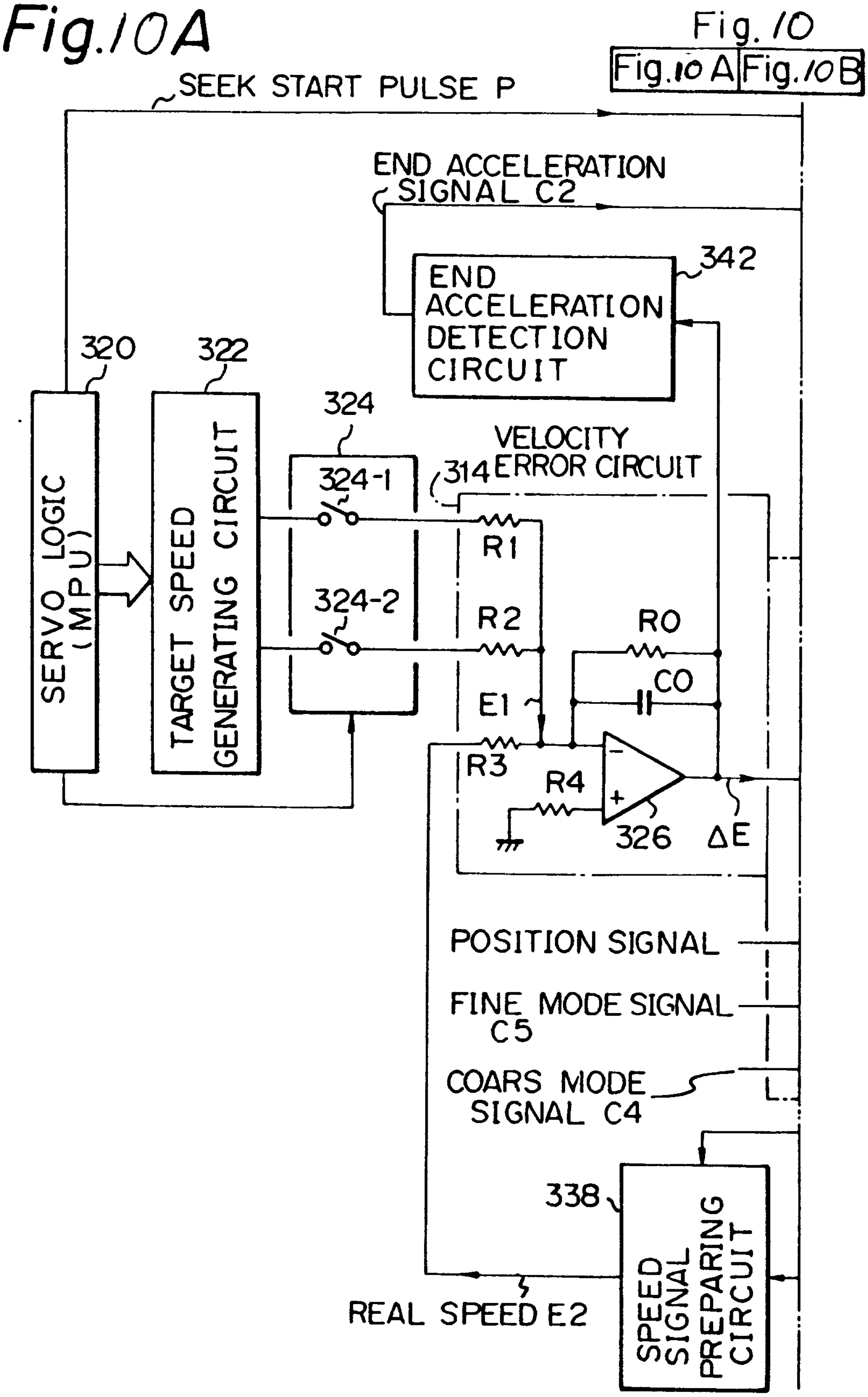


Fig.10
Fig.10 A
Fig.10 B
SEEK START PULSE P
END ACCELERATION SIGNAL C2
342
END ACCELERATION DETECTION CIRCUIT
320
322
SERVO LOGIC (MPU)
TARGET SPEED GENERATING CIRCUIT
324
324-1
324-2
VELOCITY ERROR CIRCUIT
314
R1
R2
R0
C0
E1
R3
R4
326
ΔE
POSITION SIGNAL
FINE MODE SIGNAL C5
COARS MODE SIGNAL C4
338
SPEED SIGNAL PREPARING CIRCUIT
REAL SPEED E2

Fig. 10 B

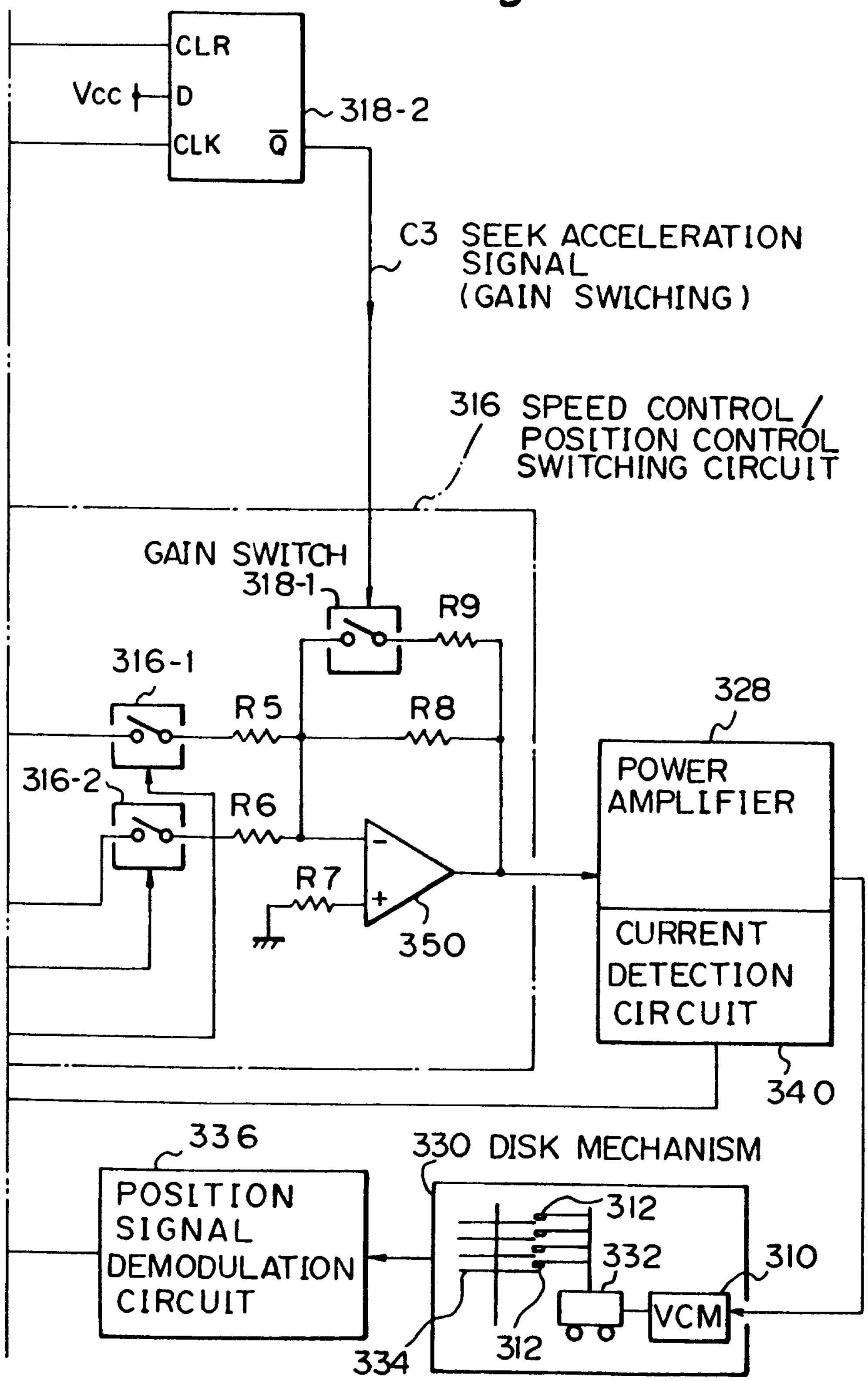
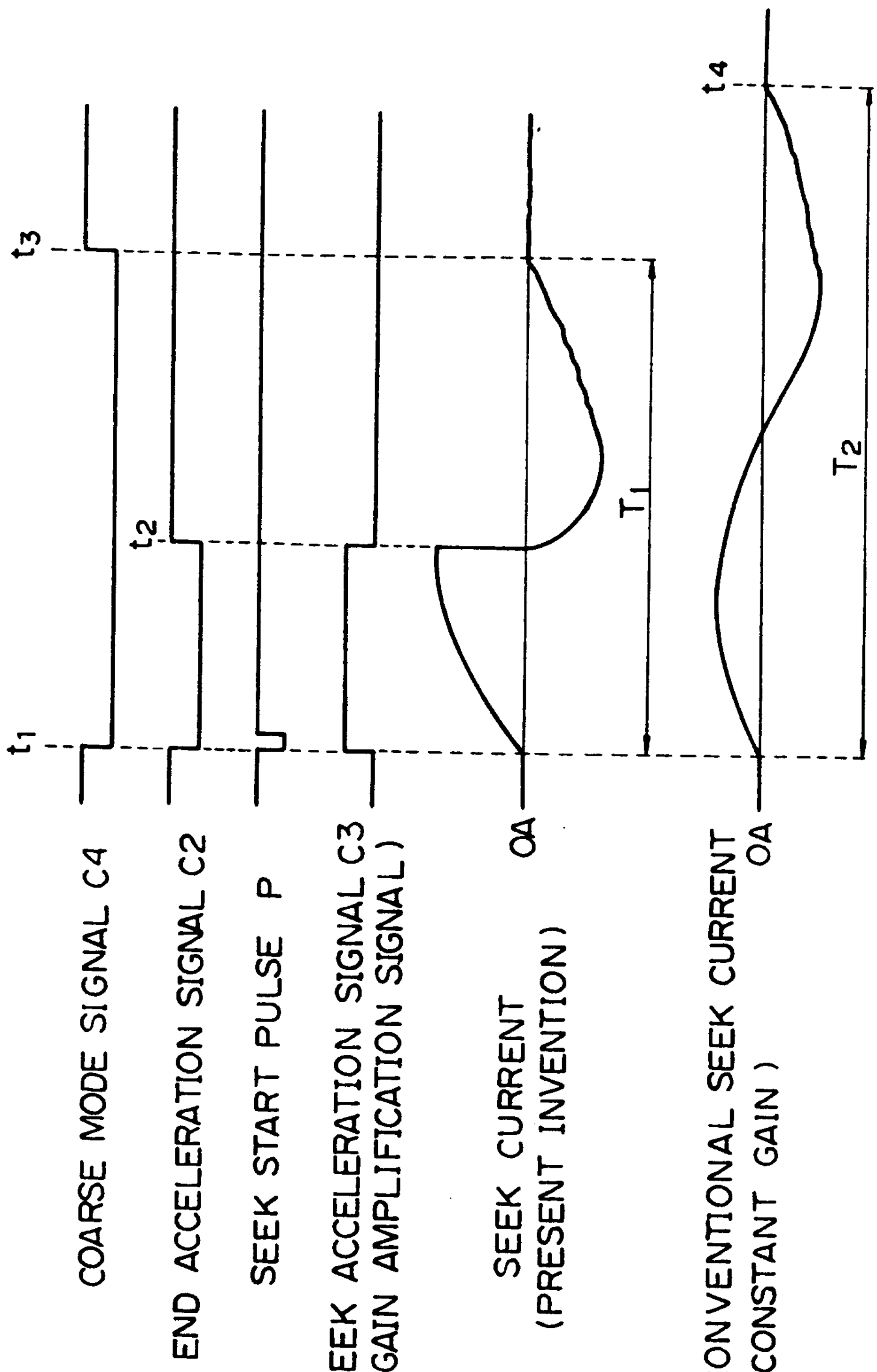

CLR
Vcc
D
CLK
Q̄
318-2
C3 SEEK ACCELERATION SIGNAL (GAIN SWICHING)
316 SPEED CONTROL / POSITION CONTROL SWITCHING CIRCUIT
GAIN SWITCH
318-1
R9
316-1
R5
R8
316-2
R6
R7
350
328
POWER AMPLIFIER
CURRENT DETECTION CIRCUIT
340
336
POSITION SIGNAL DEMODULATION CIRCUIT
330 DISK MECHANISM
312
332
310
VCM
334
312

Fig. 11


COARSE MODE SIGNAL C4
END ACCELERATION SIGNAL C2
SEEK START PULSE P
SEEK ACCELERATION SIGNAL C3
(GAIN AMPLIFICATION SIGNAL)
SEEK CURRENT
(PRESENT INVENTION)
OA
CONVENTIONAL SEEK CURRENT
(CONSTANT GAIN)
OA
t1
t2
t3
t4
T1
T2